AERONAUTICAL AND ASTRONAUTICAL ENGINEER

**VISION-BASED NAVIGATION FOR AUTONOMOUS LANDING OF
UNMANNED AERIAL VEHICLES**
Paul A. Ghyzel-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1989
Aeronautical and Astronautical Engineer-September 2000
Master of Science in Aeronautical Engineering-September 2000
Advisors: Isaac I. Kaminer, Department of Aeronautics and Astronautics
Oleg A. Yakimenko, National Research Council Senior Research Associate

The role of Unmanned Aerial Vehicles (UAVs) for modern military operations is expected to expand in the 21st Century, including increased deployment of UAVs from Navy ships at sea. Autonomous operation of UAVs from ships at sea requires the UAV to land on a moving ship using only passive sensors installed in the UAV. This thesis investigates the feasibility of using passive vision sensors installed in the UAV to estimate the UAV position relative to the moving platform. A navigation algorithm based on photogrammetry and perspective estimation is presented for numerically determining the relative position and orientation of an aircraft with respect to a ship that possesses three visibly significant points with known separation distances. Original image processing algorithms that reliably locate visually significant features in monochrome images are developed. Monochrome video imagery collected during flight test with an infrared video camera mounted in the nose of a UAV during actual landing approaches is presented. The navigation and image processing algorithms are combined to reduce the flight test images into vehicle position estimates. These position estimates are compared to truth data to demonstrate the feasibility of passive, vision-based sensors for aircraft navigation. Conclusions are drawn, and recommendations for further study are presented.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Sensors

KEYWORDS: Unmanned Aerial Vehicle, Navigation, Infrared Imaging, Image Processing, MATLAB®, Simulation

**EXPLORATION OF FIBRE CHANNEL AS AN AVIONICS INTERCONNECT FOR THE 21ST
CENTURY MILITARY AIRCRAFT**
Shawn P. Hendricks-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1989
Aeronautical and Astronautical Engineer-September 2000
Master of Science in Aeronautical Engineering-September 2000
Advisor: Russell W. Duren, Department of Aeronautics and Astronautics
Second Reader: John C. McEachen, Department of Electrical and Computer Engineering

Avionics architectures are evolving from "Federated" systems consisting of highly specialized black boxes connected together via MIL-STD-1553 and ARINC 429 data buses to "Integrated" and "Distributed" architectures. These new architectures contain high data-rate sensors, parallel processors, and shared memory with high levels of integration. These systems require a new interconnection system that overcomes the limitations of older standards. One such interconnection system is Fibre Channel. This thesis evaluates Fibre Channel as avionics interconnection standard. It begins by defining the requirements and measures of performance for an interconnection system suitable for the new avionics architectures. The requirements address technical performance, affordability, reliability, sustainability, and

maintainability considerations. The Fibre Channel standards are then compared to the requirements for the avionics interconnection system. In order to perform a technical performance evaluation of a switched fabric avionics interconnection system, a computer simulation model was developed. The OPNET Modeler® tool from OPNET, Inc. was used to model the components of an advanced avionics system. The results of this simulation demonstrated that Fibre Channel meets all the performance requirements of an avionics interconnect.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Electronics, Modeling and Simulation

KEYWORDS: Fibre Channel, Interconnect, Avionics, Bandwidth, Modeling, Simulation

ELECTRICAL ENGINEER

**A METHOD OF INCREASING THE KINEMATIC BOUNDARY OF AIR-TO-AIR
MISSILES USING AN OPTIMAL CONTROL APPROACH**
Robert D. Broadston-Lieutenant Commander, United States Navy
B.S.E.E., United States Naval Academy, 1984
Electrical Engineer-September 2000
Master of Science in Electrical Engineering-September 2000
Advisor: Robert G. Hutchins, Department of Electrical and Computer Engineering
Second Reader: Harold A. Titus, Department of Electrical and Computer Engineering

Current missile guidance laws are generally based on one of several forms of proportional navigation (PN). While PN laws are robust, analytically tractable, and computationally simple, they are only optimal in a narrow operating regime. Consequently, they may not optimize engagement range, time to intercept, or endgame kinetic energy. The advent of miniaturized high-speed computers has made it possible to compute optimal trajectories for missiles using command mid-course guidance as well as autonomous onboard guidance. This thesis employs a simplified six degree of freedom (6DOF) flight model and a full aerodynamic 6DOF flight model to analyze the performance of both PN and optimal guidance laws in a realistic simulation environment which accounts for the effects of drag and control system time constants on the missile's performance. Analysis of the missile's kinematic boundary is used as the basis of comparison. This analysis is immediately recognizable to the warfighter as an engagement envelope. The guidance laws are tested against non-maneuvering and maneuvering aircraft targets and against a simulation of a cruise missile threat. An application of the 6DOF model for a theater ballistic missile interceptor is presented.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Missile Guidance Laws, Proportional Navigation, Optimal Control, Kinematic Boundary

AN EXTENDED KALMAN FILTER FOR QUATERNION-BASED ATTITUDE ESTIMATION
João Luís Marins-Lieutenant Commander, Brazilian Navy
B.S., University of São Paulo, Brazil, 1991
Electrical Engineer-September 2000
Master of Science in Electrical Engineering-September 2000
Advisors: Xiaoping Yun, Department of Electrical and Computer Engineering
Eric R. Bachmann, Department of Computer Science
Robert G. Hutchins, Department of Electrical and Computer Engineering

This thesis develops an extended Kalman filter for real-time estimation of rigid body motion attitude. The filter represents rotations using quaternions rather than Euler angles, which eliminates the long-standing problem of singularities associated with those angles. The process model converts angular rates into quaternion rates, which are in turn integrated to obtain quaternions. Gauss-Newton iteration is utilized to find the quaternion that best relates the values of linear accelerations and earth magnetic field in the body coordinate frame and the earth coordinate frame. The quaternion obtained from the optimization algorithm is used as part of the observations for the Kalman filter. As a result, measurement equations become linear. The computational requirements related to the extended Kalman filter developed using this approach are significantly reduced, making it possible to estimate attitude in real-time. Extensive static and dynamic simulation of the filter using Matlab proved it to be robust. Test cases included the presence of large initial errors as well as high noise levels. In all cases the filter was able to converge and accurately track attitude.

DESIGN OF AN ULTRA-WIDEBAND DIRECTIONAL ANTENNA FOR A GIVEN SET OF DIMENSION CONSTRAINTS

Marcio Moreira da Silva-Lieutenant Commander, Brazilian Navy
B.S., Escola Naval, 1985
B.S.E.E., Universidade de São Paulo, December 1991
M.S.E.E., Universidade de São Paulo, April 1996
Electrical Engineer-September 2000
Master of Science in Electrical Engineering-September 2000
Advisors: Ramakrishna Janaswamy, Department of Electrical and Computer Engineering
Jovan E. Lebaric, Department of Electrical and Computer Engineering
Maj David V. Adamiak, USMC, Department of Electrical and Computer Engineering

This research encompasses the preliminary and detailed design phases of a directional high-power UHF antenna that fits within a restrictive cylinder. The antenna design was limited to a free-space situation.

In the preliminary design phase, various antenna configurations were evaluated through simulation using the Numerical Electromagnetics Code (GNEC) to determine the optimum design. The optimization process was divided into consecutive steps. The best antenna from one step was further developed in the next step, and so on, until the final preliminary design, the RATTLE-1 antenna, was obtained. The Antenna Comparison Technique (ACT), a procedure that compares normalized grades evaluated for each antenna, was used to choose the optimum antenna configuration.

The detailed design phase concentrated on solving the impedance matching problem between the antenna and the transmission line. The final solution entailed the use of a tapered coaxial line balun. The performance of the RATTLE-1 integrated balun was evaluated through simulations using the High-Frequency Structure Simulator (HFSS) and prototype measurements.

MECHANICAL ENGINEER

**COMPUTATIONAL FLUID DYNAMICS PREDICTION OF SUBSONIC AXIS-SYMMETRIC
AND TWO-DIMENSIONAL HEATED FREE TURBULENT AIR JETS**

Michael D. DeWulf-Lieutenant, United States Navy
B.S., Iowa State University, 1993
Mechanical Engineer-September 2000
Master of Science in Mechanical Engineering-September 2000
Advisor: Knox T. Millsaps, Jr., Department of Mechanical Engineering
Second Readers: Garth V. Hobson, Department of Aeronautics and Astronautics
Arthur Shavit, Department of Mechanical Engineering
Terry R. McNelley, Department of Mechanical Engineering

A study was conducted to evaluate the accuracy of a commercial computational fluid dynamics (CFD) code (CFDRC-ACE+) for predicting incompressible air jet flows with simple geometries. Specifically, the axis-symmetric and two-dimensional heated air-jets were simulated using a standard k-ε turbulence model. These CFD predictions were directly compared to an extensive compilation of experimental data from archive literature. The round jet results indicated that the code over-predicted the velocity-spreading rate by 24% and the temperature-spreading rate by 29%. In addition, the centerline velocity and temperature decay rates were also over-predicted by 21% and 30%, respectively. The geometric and kinematic virtual origins were over-predicted, as well, by approximately 7.5 diameters for the velocity profiles and 10.5 diameters for the temperature profiles. The planar jet simulation was generally closer to experimental data ranges, with an under-prediction of the velocity-spreading rate of approximately 17% with an over-predicted temperature-spreading rate of 12%. The centerline velocity and temperature decay rates were both under-predicted at 22% and 27%, respectively. Again, the geometric and kinematic virtual origins were over-predicted by approximately 7.5 slot heights for the velocity profiles and 10.5 slot heights for the temperature profiles.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Computational Fluid Dynamics (CFD), Eductor, Ejector, Gas Turbine, Exhaust, Axisymmetric Jet, Two-Dimensional Jet, Air Jet, Free Turbulent, Jet